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PERFORMANCE OF PALLETS WITH HARDBOARD DECKS OF VARIED DENSITY.(U)
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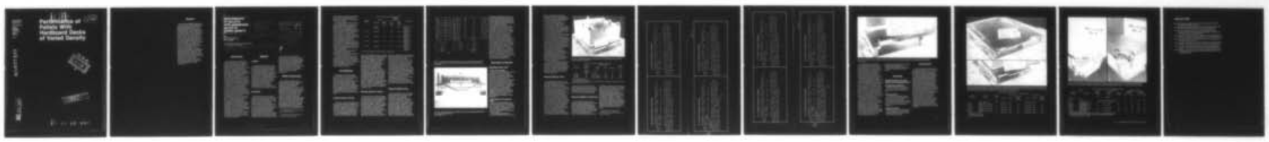

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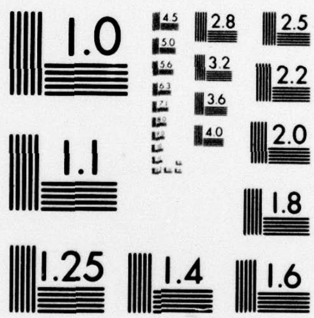
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FPL 340

1979

Performance of Pallets With Hardboard Decks of Varied Density

Abstract

This study investigated the prospect of using hardboard advantageously for shipping pallet construction. This is especially desirable because of the potentially large volume of logging and milling waste that could be used with low-grade lumber for this purpose. The work indicated that notched stringer pallets of the very common 48- by 40-inch size and made with hardboard decks of various densities required use of "medium-density hardboard" of a thickness greater than three-fourths of an inch to equal or exceed that of similar lumber pallets having decks of nominal 1-inch red oak. This conclusion was based on handling impact, bending stiffness, and diagonal rigidity test results. Furthermore, the data indicated that hardboard-lumber pallets do not rack nearly so much, but crush at the corners more easily, when compared to their all-lumber counterparts. This work should be important to anyone concerned with the use of hardboard in pallet construction.

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PERFORMANCE OF PALLETS WITH HARDBOARD DECKS OF VARIED DENSITY.

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10 By
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U.S. Department of Agriculture

9 Forest Service research paper,

Introduction

The potential use of hardboard in pallet construction is large. Such an outlet would enhance the market for hardboard and, thereby, promote usage of limbs, crooked pieces, milling scrap, etc.—material presently not being used after logging. This work was done to determine the suitability of pallets made with hardboard decks of varied density. Comparison of performance was based on the nailed wood notched stringer style of 48- by 40-inch partial 4-way entry returnable pallet because of its present wide use in domestic and international shipment.

Related work includes a report on the basic mechanical properties of three medium-density hardboards made from virgin pulpwood (8).[2] The moisture-related physical properties of dry-formed medium-density hardboards made from various urban wood wastes are developed in (3), and the performance of 9-block, single-deck pallets of varied size, and made from new or reclaimed hardboard is discussed in (2). Additionally, the serviceability of pallets of similar style and made from virgin medium-density hardboard of varied thickness was evaluated in (7). The principal objective of this work, therefore, was to develop information that could lead to successful use of hardboard for pallet construction and use. This, in turn, would permit more effective utilization of low-grade wood fiber.

Material

Lumber

A sufficient supply of green rough lumber which remained from earlier Forest Products Laboratory research (7) was used for pallet construction. The unsurfaced nominal 1- and 2-inch No. 3A common red oak boards were removed from underwater storage, surfaced, and cut into pieces for pallet construction according to NWPCA Grade A (4). At that time the pieces were trimmed to the proper size, randomized, enclosed by 6-mil polyethylene film, and stored temporarily in a room maintained at 36° F and 82 percent relative humidity.

Hardboard

A sufficient number of hardboard sheets was manufactured for this work by Celotex Corp. at Deposit, N.Y. and used to make the top decks of 40 test pallets. A check of the material indicated that its nominal density was 27, 39, 42, and 45 pounds per cubic foot at 7 percent moisture content. The fiber was treated with an 8-percent urea solids binder fortified with 6 percent melamine after temporary storage in the dried condition. A partial identification of the component fibers indicated that the hardboard was made primarily from maple, basswood, cherry, and ash. However, beech and birch had also been used appreciably. Other species, such as aspen, willow, cottonwood, oak, and yellow poplar were also used infrequently. The moisture content of the hardboard was maintained at less than 7 percent (based on the ovendry weight) from reception until use in pallet construction.

Pallet Construction

Shortly after they were cut, the lumber parts were nailed together as pallets. The green lumber was transferred in the described polyethylene bags, from the 36° F, 82 percent relative humidity room to the pallet assembly area and assembled as pallets in a minimum length of time. Transfer of parts was limited to the equivalent of two pallets per trip in order to minimize drying before assembly as pallets. Both pallet designs employed in this work were basically 48- by 40-inch notched stringer, flush type nonreversible pallets. The pallet types differed only in that complete hardboard panels were used for the upper decks of the experimental style,

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]Underlined numbers in parentheses refer to literature cited at end of this report.

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while boards comprised the top decks of the lumber comparative control pallets. The details of the two designs are shown in figure 1.

Helically-threaded 2½- by 0.120-inch hardened steel pallet nails having an average MIBANT bending angle of 17 degrees were used to assemble the pallet parts (5). The staggered nailing patterns of the hardboard decks and the top deckboards of control pallets are shown in figure 1. The same total number (69), size, and type of nails were used to attach both the top deckboards of controls and the top decks of hardboard pallets. However, the spacing between nails was about 3/32 inch greater with hardboard, because of the continuous nature of the sheet. The nails on the top and bottom sides of the stringers were staggered to reduce the chances of splitting.

A summary of the principal pallet distinguishing features and combinations of variables investigated in this work is given in table 1.

Following construction, the pallets were stored under uncontrolled interior conditions for at least 1 month before testing was begun. This was considered to be a reasonable drying time to minimize the effect of drying upon change in pallet strength.

Table 1.—A summary of principal pallet features

Pallet designation	Top deck[1]		Average weight (lb)		Pallet design
	Composition	Average density	At fabrication	After conditioning	
		Lb/ft³			
C	Lumber (controls)	—	110.2	65.4	Described under "pallet construction" and fig. 1A
OH-1104	Hardboard	27	80.9	55.7	Described under "pallet construction" and fig. 1B
OH-1105	Hardboard	39	92.2	67.8	Described under "pallet construction" and fig. 1B
OH-1106	Hardboard	42	94.5	69.7	Described under "pallet construction" and fig. 1B
OH-1102	Hardboard	45	95.5	70.5	Described under "pallet construction" and fig. 1B

[1]Note: All stringers and bottom deckboards were red oak lumber.

Test Methods

Fifty pallets, including 10 lumber control pallets, were constructed and tested to destruction. Essentially, this was done by two methods: (A) destructive handling impact testing and (B) nondestructive static bending testing followed by diagonal rigidity testing (i.e., destructive cornerwise free-fall drop testing). Twenty hardboard-lumber pallets and five lumber controls were tested according to (A), and a similar group was evaluated according to (B).

Handling Impact Testing

The primary purpose of this portion of the tests was to measure resistance of the pallet to one common form of rough handling of pallets during ordinary forklift truck handling in service. Tests of this nature were conducted with a conventionally-equipped forklift truck—i.e., without attachments such as the Forest Products Laboratory "impact panel" (6). In essence, in each handling impact the forklift truck traveled forward at an average speed of 2.00 miles per hour until it contacted the stationary, loaded pallet; stopped; and was withdrawn from the loaded pallet. The forks were tilted 4 degrees forward during tests, and the registered individual impact speeds varied between extremes of 1.81- and 2.13 miles per hour. The height of the forks was adjusted so that the upper sides contacted the pallet 8 inches from the right angles of the forks. Testing was repeated as described until the pallet reached the condition where repair would be required for further use. Also, testing of hardboard-lumber pallets was halted if "forkbite" progressed to 2 inches or more in depth. The equipment and method covered by the procedure are given in (6).

Bending Stiffness Testing

Shippers are wary of flexible pallets, especially when used with heavy goods and rack storage, due to the likelihood of personal injury or damage to the goods being handled. Therefore, as is specified by ASTM D 1185-73 (1), each of the 25 pallets in this set was loaded nondestructively in bending at the quarter points of the 36- and 44-inch spans by a universal testing machine at 0.1 inch per minute. The loading progressed from zero until a linear, easily read, load-deflection record was produced. Deflection at the midpoints of each span was sensed by the movable elements of two linear variable differential transformers (LVDT). The LVDT's were mounted on metal yokes suspended from the ends of the two outer stringers. The pallet was then unloaded and the described loading cycle was repeated twice more in order to generate representative data. At this point, the pallet was rotated 90 degrees in the same plane, and cyclic loading was repeated in the same manner three more times. The resulting signal voltages were fed into an X-Y recorder, and average stiffness was then calculated from the resulting data for the linear portion of each curve. One view of the test set-up is shown in figure 2.

Diagonal Rigidity Tests

Racking of pallets out of rectangular shape during use can result in costly time delays. This is especially troublesome if they are used in an automatic palletizer of a continuous conveyor or in computer-controlled automated systems. Obviously, it is also costly to replace or repair them if they become damaged excessively during this type of usage. Therefore, these tests were conducted as a part of the general evaluation of the suitability of hardboard for pallet construction in order to compare the diagonal rigidity quality of hardboard-lumber pallets with

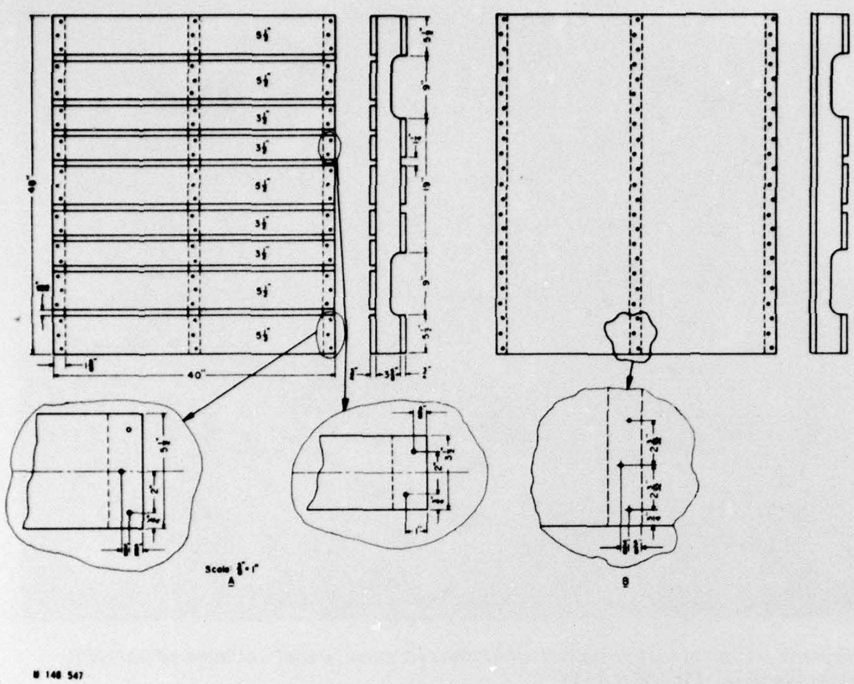

Figure 1.—Pallet designs evaluated in this work. (A) lumber control pallet with spaced top deckboards and (B) experimental pallet with hardboard top deck. (M 146 547)

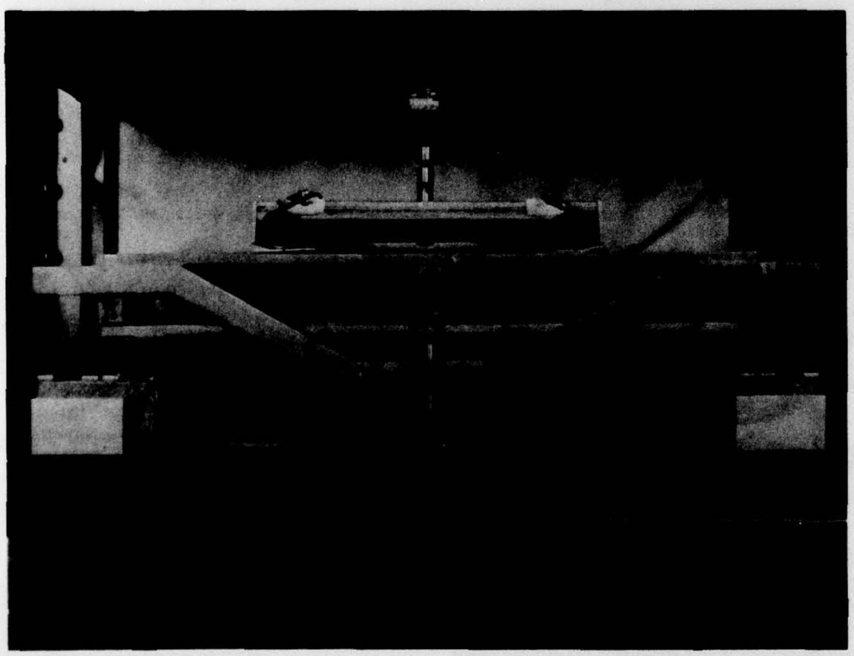

Figure 2.—Test configuration for pallet in fixture of a universal testing machine during bending stiffness test. (M 145 065-11)

the standard oak pallet controls. The same set of 25 pallets that had received bending stiffness tests were also used for these diagonal rigidity tests because of their undamaged condition following bending stiffness evaluation.

Each pallet was dropped from 40 ± 1/8 inches above a 2-inch-thick steel plate embedded in the concrete floor and supported by bedrock. Prior to release, the pallet was suspended from such a position on the corner so that the diagonal across the top deck of the pallet was vertical to the dropping surface. Individual pallets were dropped 12 times or until the pallet damage reached a point that it would have been unserviceable without repair. Racking of the pallet was monitored by changes in the original length of diagonals measured approximately 1.4 inches in from either original corner. Changes in the length of pairs of diagonals on the adjacent top and bottom sides of the pallets were averaged for each drop and used as a measure of pallet rigidity. The test procedure and data report complied with that specified in (1).

Discussion of Results

Handling Impact Tests

Lumber control pallets

Typical failure involved splitting of the leading portion of the top edge deckboard, ("leadboard"), together with partial withdrawal and bending of the nails. Occasionally, the top leadboard was completely free from one or two of the stringers of each pallet (fig. 3). The total number of impacts required to produce failure varied from 4 to 15 and averaged 8. It's noteworthy that "forkbite"—i.e., appreciable indentation at the contact points between the forklift truck and the top leadboards—did not occur. This was probably due to the presence of adequate shear resistance in the top leadboards.

Lumber pallets with hardboard decks

Hardboard-lumber pallets having hardboard decks 39 pounds per cubic foot or more were from 2.7 to 8.5 times more resistant to handling impact tests than the lumber pallet controls. A summary of test results of this nature is shown in table 2.

Unlike the damage sequence previously described for lumber control

pallets, hardboard-lumber pallets developed "forkbite" progressively, as the testing continued. Specifically, the inclined forks applied concentrated, horizontal, and vertical force components to the pallets during handling testing. These forces produced shear stresses, both parallel and perpendicular to the neutral plane of the hardboard panels, together with a bending stress accompanying upward curl of the panel, as forkbite progressed. Testing in each series was stopped arbitrarily at 2 inches—i.e., the point at which repair probably would have been required, had the pallet been in service. Typical 2-inch forkbite failure obtained with a red oak pallet having a 42-pound-per-cubic-foot top deck is shown in figure 4. This pallet received a series of 18 handling-type impacts by a conventional 2-ton forklift truck traveling at 2.0 miles per hour.

Quantitatively, the resistance of hardboard panels in all thicknesses to forkbite was lower than the nail withdrawal resistance of even the lightest density panels used (27 lb/ft^3), and none of the nail joints failed by nailhead "pullthrough."

The condition of a pallet made with a 27-pound-per-cubic-foot hardboard deck after only one impact is shown in figure 5A. In contrast, the well-ordered condition of a pallet of the same style made with a 45-pound-per-cubic-foot hardboard deck, is shown after 66 impacts in figure 5B.

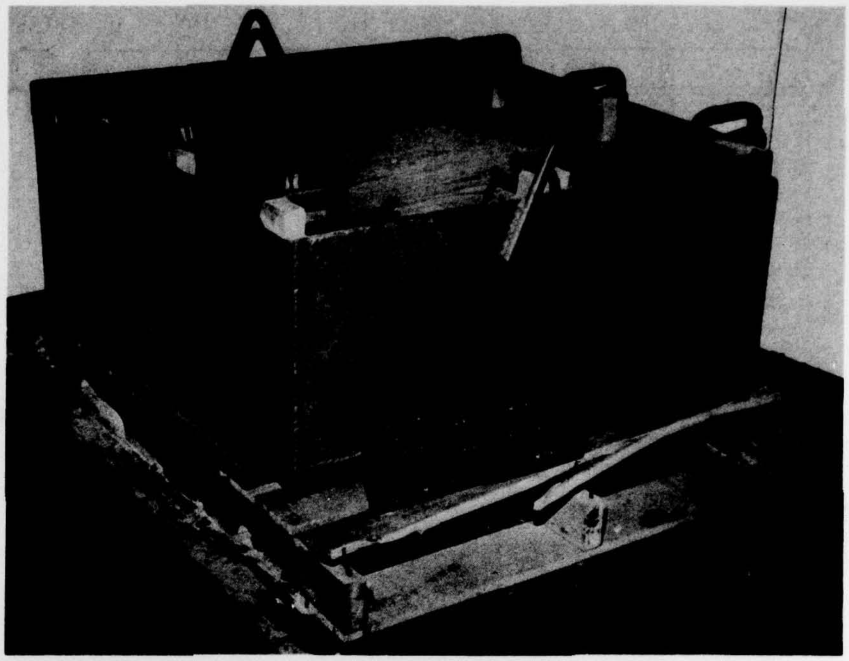

Figure 3.—Typical failure pattern of lumber (control) pallet because of handling impact testing. (M 145 510-1)

Table 2.—A summary of handling impact test results

Pallet designation	Density of hardboard top deck[1]	Impacts to failure			Pallet performance ratio[3]
		Individual values	Range	Average[2]	
	Lb/ft^3				
C	Lumber (controls)	5, 4, 15, 9, 5	4-15	8	(1.00)
OH-1104	27	1, 4, 3, 3, 1	1-4	2	.32
OH-1105	39	8, 37, 20, 17, 20	8-37	20	2.68
OH-1106	42	18, 11, 73, 18, 17	11-73	27	3.61
OH-1102	45	66, 15, 147, 46, 47	15-147	64	8.45

[1]At 7 pct moisture content.
[2]Rounded off to nearest whole unit.
[3]The average values for the lumber (control) pallets divided into corresponding values for pallets having hardboard decks and lumber parts.

Bending Stiffness Tests

The average slope for the 15 load-displacement graphs was computed for each pallet design and loading orientation. The resulting values for slope, together with the corresponding values for range, are presented in table 3. Stiffness ratios are also given to indicate the performance of individual hardboard-lumber pallet designs relative to that of all-lumber pallets of similar size and design. Perhaps the most important observation concerns the stiffness ratio for hardboard-lumber pallets, as referred to lumber pallets of the same size and length. Specifically, the hardboard-lumber pallets were about 1.0 to 1.5 times as stiff as their lumber counterparts when tested with the span in the direction of the stringers. However, comparative loading tests of the same pallets with the span perpendicular to the stringers indicated that the hardwood-lumber pallets developed a maximum stiffness (for pallets with 45-pound per cubic foot hardboard decks) of about two-thirds that of the all-lumber control pallets.[3]

Diagonal Rigidity Test Results

Failure of the all-lumber control pallets involved crushing of the corners of the top and bottom deckboards. When hardboard-lumber pallets were tested, crushing of the hardboard top panel occurred. Often the stringer failed in bending at the beginning (outer end) of the notch because this area experienced the greatest stress. More specifically, lateral failure of the stringer was caused by a combination of a sharp reduction in cross-sectional area at the beginning of the notch and the nearness of the laterally-impacted end of the stringer (figure 6A). Often, the stringer end also failed in shear parallel to the grain, as shown. The other, common failure pattern for this type of test is shown in figure 6B. In this failure pattern the stringer remained essentially intact, and the applied impact energy was absorbed mainly by crushing of the ends of all pallet parts forming the corner.

[3]Results presented in (7) suggest that comparable stiffness can be attained with 1-inch hardboard thickness.

U.S. Forest Products Laboratory.

Performance of pallets with hardboard decks of varied density, by Robert K. Stern. Madison, Wis., For. Prod. Lab., 1979.
12 p. (USDA For. Serv. Res. Pap. FPL 340).

Reports the results of a study investigating the prospect of using hardboard in the construction of shipping pallets. This use would permit more effective use of low-grade wood fiber. Comparisons were made using red oak lumber and hardboard pallets.

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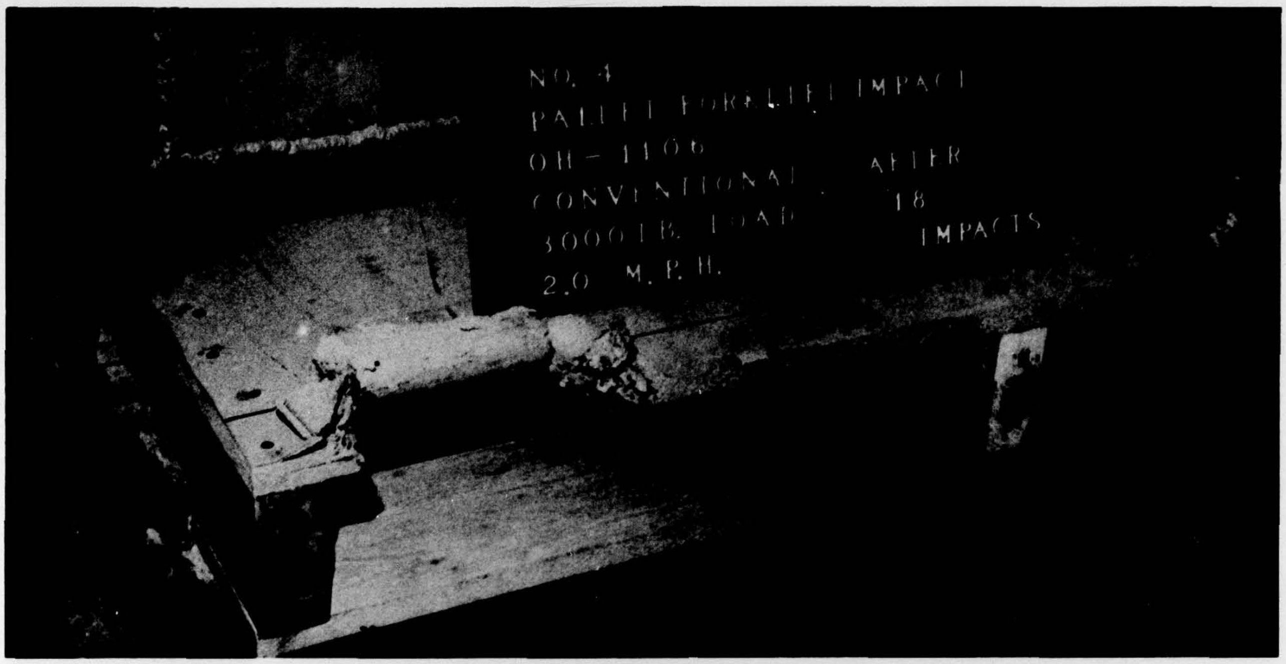

Figure 4.—"Forkbite" into the edges of 42-Pounds-per-cubic-foot hardboard panel during handling impact testing. (M 145 510-6)

It is noteworthy that hardboard-lumber pallets distorted a maximum of about one-tenth as much as the all-lumber pallets during rough handling testing of this type. This dimensional stability would be a strong asset in automatic palletizing operations, because pallet racking is a frequent cause of line shutdown with any of the pallets in this work (stringer type).

"Nailhead pullthrough," as happened under similar testing of 9-block-type pallets with hardboard decks (7), did not occur. This was true even with the 27-pound-per-cubic-foot hardboard (the lightest material included in this study). It seems likely that this change in the failure mechanism was caused by the addition of the much stiffer stringer to replace the more flexible stringer board in the basic pallet designs. Thus, much less flexure of the hardboard deck and nailhead pullthrough resulted.

As indicated by figure 6, the test endpoints—i.e., the stage at which the pallet would have been unserviceable unless repaired—were indistinct. Nevertheless, behavioral patterns are suggested by the resulting data. A summary of the quantitative results of this portion of the tests is given in table 4. As indicated, the number of impacts given to each pallet was 12—the maximum specified under (1). In contrast, the average number of similar impacts that caused failure of hardboard-lumber pallets ranged from 5.2 (45 lb/ft³ decks) to 8.6 (27 lb/ft³ decks).

Summary

Characteristics of Lumber Pallets with Hardboard Decks

Handling impact resistance

Pallets with decks 39 pounds per cubic foot, or higher, were superior to lumber pallets of the same type and size.

Bending stiffness

The maximum average stiffness of hardboard-lumber pallets was about two-thirds that of their lumber counterparts when loaded with the span perpendicular to the stringers, but up to about 50 percent higher along the stringers.

Diagonal distortion

Was only one-tenth (at worst) that of all-lumber pallets, but the hardboard-lumber pallets also failed sooner than their lumber counterparts.

Conclusions

Lumber pallets with hardboard decks of the type evaluated in this work would be suitable for some uses now being served by returnable red oak pallets. They would be especially advantageous in mechanized warehouse palletizing and handling operations because of their low diagonal distortion tendency. Additionally, the likelihood of frequent free-fall dropping from appreciable height would probably be less for this type of service. The bending stiffness for hardboard lumber pallets of this size and type is less when the load is applied with the span perpendicular to the stringers, but equal to or higher with the span in the direction of the stringers when compared to similar lumber pallets made with the same deck member thickness. The results of this work are promising enough to warrant consideration of further investigation using 39 pounds per cubic foot (or greater) density material and sufficient thickness to obtain satisfactory bending stiffness.

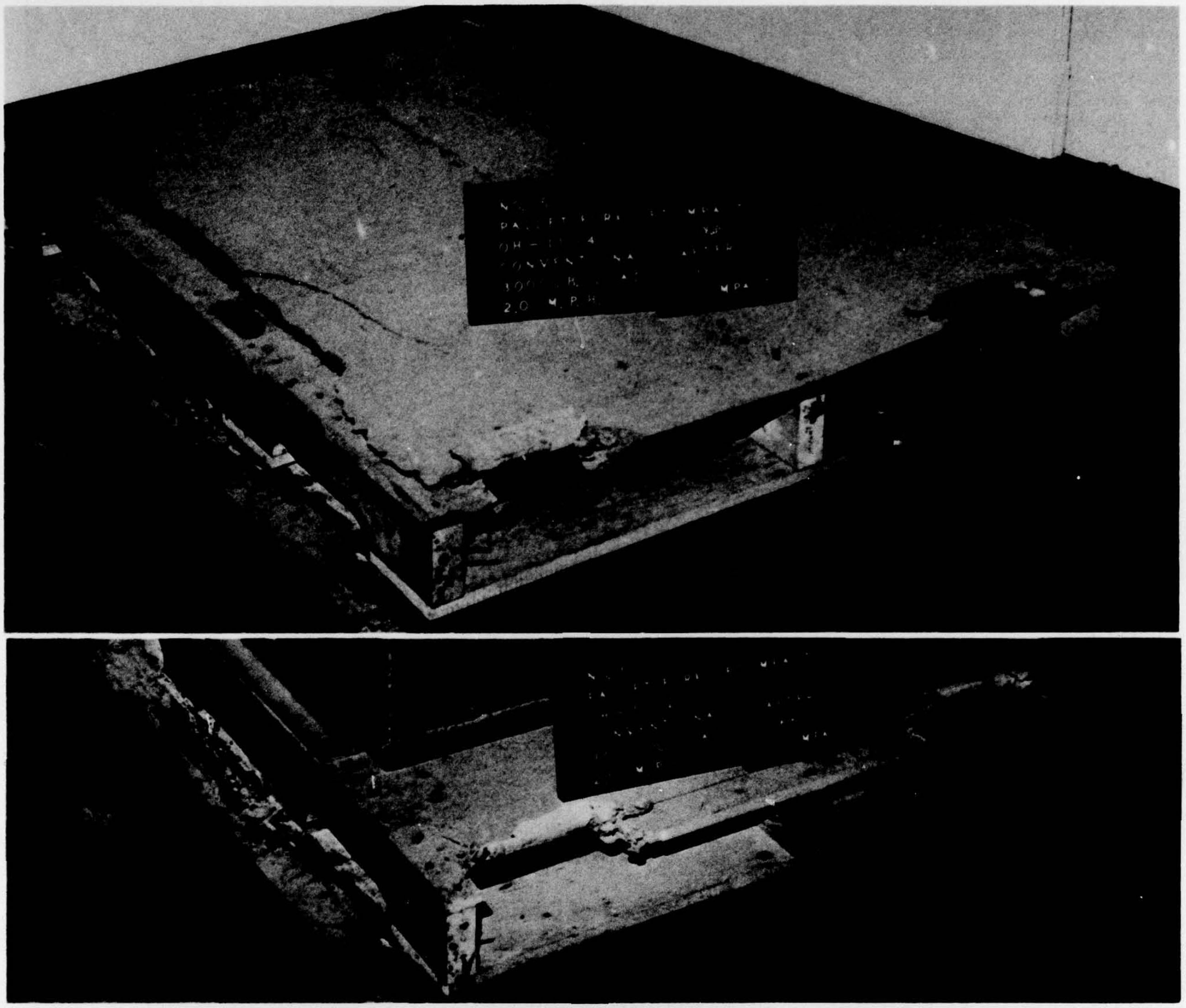

Figure 5.—Extremes in the performance of hardboard-lumber pallets during handling impact testing. (A) 27 pounds-per-cubic-foot hardboard top deck after one impact (showing shear failure) and (B) shear failure of 45 pounds-per-cubic- foot hardboard deck after 66 handling impacts by the forklift truck. (M 145 510-9) (M 145 510-12)

Table 3.—Bending stiffness test results

Pallet designations	Pallet composition	Top deck density[1]	Pallet stiffness (lb/in.) 36-inch span[2] Range	36-inch span[2] Average	36-inch span[2] Hardboard pallets / Controls	44-inch span[3] Range	44-inch span[3] Average	44-inch span[3] Hardboard pallets / Controls
		Lb/ft³						
C	Lumber (Controls)	—	5,950-7,810	6,540	—	9,620-16,130	12,280	—
OH-1104 No. 6-10	Lumber pallet with hardboard deck	27	2,910-3,520	3,230	.493	11,630-14,290	12,410	1.012
OH-1105 No. 6-10	Lumber pallet with hardboard deck	39	3,500-4,460	3,790	.579	15,150-20,000	17,200	1.401
OH-1106 No. 6-10	Lumber pallet with hardboard deck	42	3,820-4,630	4,230	.647	14,290-17,860	15,590	1.270
OH-1102 No. 6-10	Lumber pallet with hardboard deck	45	3,880-4,670	4,260	.650	15,630-22,730	18,640	1.518

[1]At 7 pct moisture content.
[2]Perpendicular to the stringers.
[3]In the direction of the stringers.

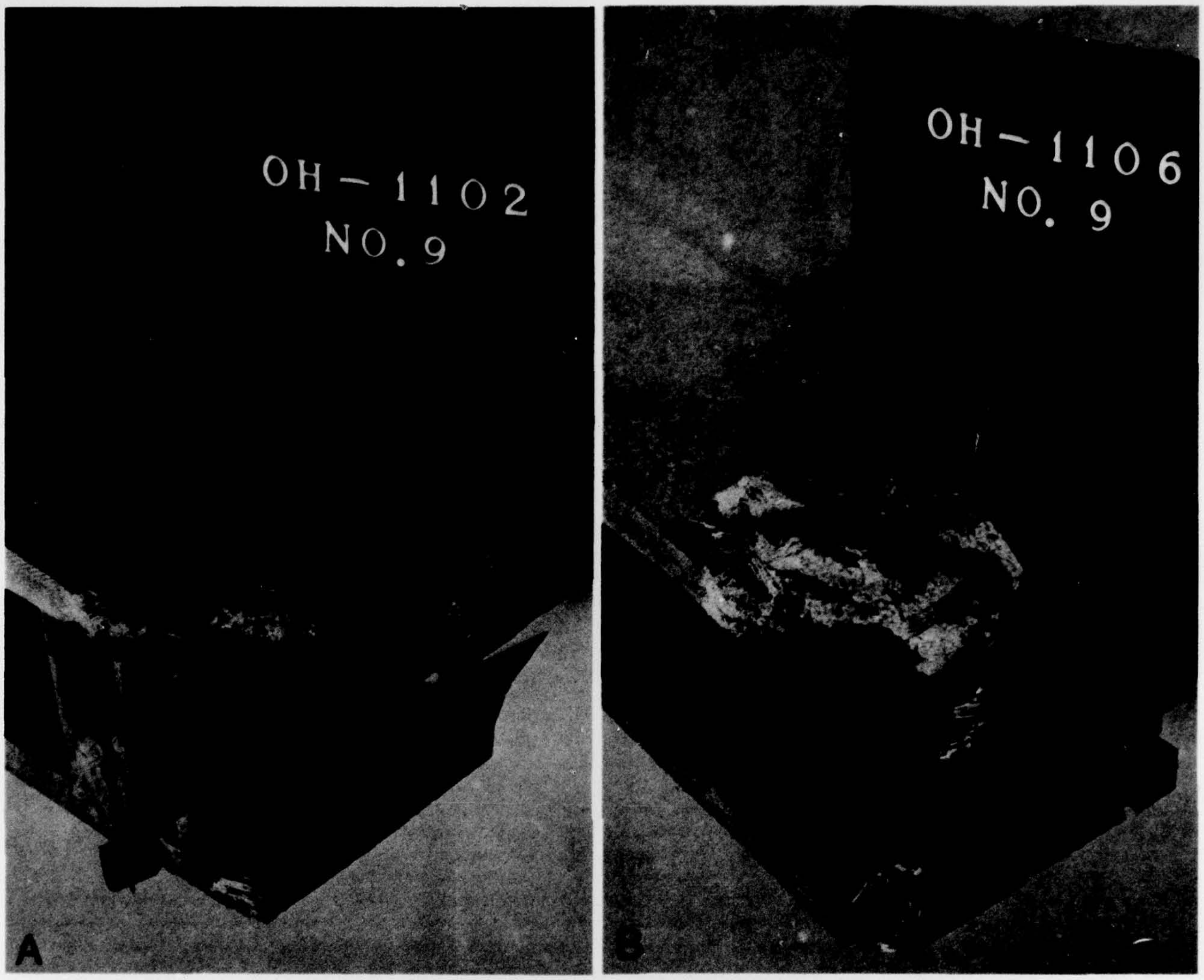

Figure 6.—Common types of pallet failure resulting from diagonal rigidity testing. (A) broken stringer caused by severe bending stress and (B) typical damage wherein the stringer essentially remained intact. (M 145 274-6) (M 145 272-4)

Table 4.—Data summary resulting from diagonal distortion tests

Pallet data		Hardboard deck density[1]	Drops to failure		Average pallet distortion[2]			
Specimen designation	Composition		To individual pallets	Group average	Diagonals A-B, E-F (In.)	Diagonals A-B, E-F (Pct)	Diagonals C-D, G-H (In.)	Diagonals C-D, G-H (Pct)
		Lb/ft³						
			CONTROLS					
C-36, -42, -43, -54, and -64	All lumber	—	[3]—	12	[4]−1.51	−2.54	+1.44	+2.42
			PALLETS WITH HARDBOARD DECKS					
OH-1104 Nos. 6-10	Hardboard deck, lumber parts otherwise	27	12, 7, 11, 4, and 9	8.6	−.11	−.19	+.06	+.11
OH-1105 Nos. 6-10	Hardboard deck, lumber parts otherwise	39	5, 4, 12, 3, and 12	7.2	−.12	−.20	+.06	+.11
OH-1106 Nos. 6-10	Hardboard deck, lumber parts otherwise	42	12, 10, 8, 4, and 12	9.2	−.15	−.25	+.03	+.05
OH-1102 Nos. 6-10	Hardboard deck, lumber parts otherwise	45	7, 5, 3, 5, and 6	5.2	−.11	−.19	−.06	+.10

[1]At a moisture content less than 7 pct.
[2]Based on overall change in length of diagonals until failure occurred or dropping was halted at 12.
[3]All pallets in this group remained intact after 12 drops, but they were also severely racked.
[4]"−" indicates a loss of length; "+" a gain.

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